

Chapter 9 – Statistical Analysis of Candlewood Drive/ Gary Avenue Intersection – Analysis II

This analysis examined only the operation of the Candlewood Drive/ Gary Avenue (CG) intersection; however, under four operational scenarios (Analysis II). Methods similar to the statistical analysis techniques used to compare the operation of the CG intersection with the two comparable intersections (analysis I) were used here. The four Analysis II scenarios were:

1. 2S - two-way STOP control with single lane approaches with the STOP signs facing the east and west (Gary Avenue) approaches. This represents traffic control in place prior to construction of the roundabout;
2. 4S - four-way STOP control with single lane approaches. This represents one of the citizen requested intersection configurations as an alternative to roundabout installation;
3. 4L - four-way STOP control with multi-lane approaches. This also represents one of the citizen requested intersection configurations as an alternative to roundabout installation. For the multi-lane approach condition, each approach was modeled with a separate left turn lane and shared through/ right lane;
4. RA - Roundabout intersection control. This is what was constructed at the intersection.

The four intersection scenarios were evaluated under twenty-two sets of traffic loadings. Those traffic loadings were the ones gathered from the field and previously used in Analysis I. Operation at the four intersection scenarios was modeled using SIDRA. The measures of effectiveness (MOEs) used in the analysis of the CG intersection scenarios as well as the statistical methodology was the same as used previously. The following sections contain the results of the statistical analysis of the intersection under the four intersection scenarios.

Plots are shown with lines between the data points for readability purposes only. No conclusions should be made as to the lines indicating the presence of a distribution. Note that the rankings used in the statistical tables are based on results of the statistical tests used and are provided to assist the understanding of the results for the reader.

Section 9.1 – 95 Percentile Queue at Candlewood Drive/ Gary Avenue (II)

The 95 percentile queue as described previously represents the bounds of the queue at the intersection. The 95 percentile queue values are shown with regard to the amount of entering traffic in Table 39 and Note: Lines between data points are used only to aid in the readability of the figure.

Figure 21.

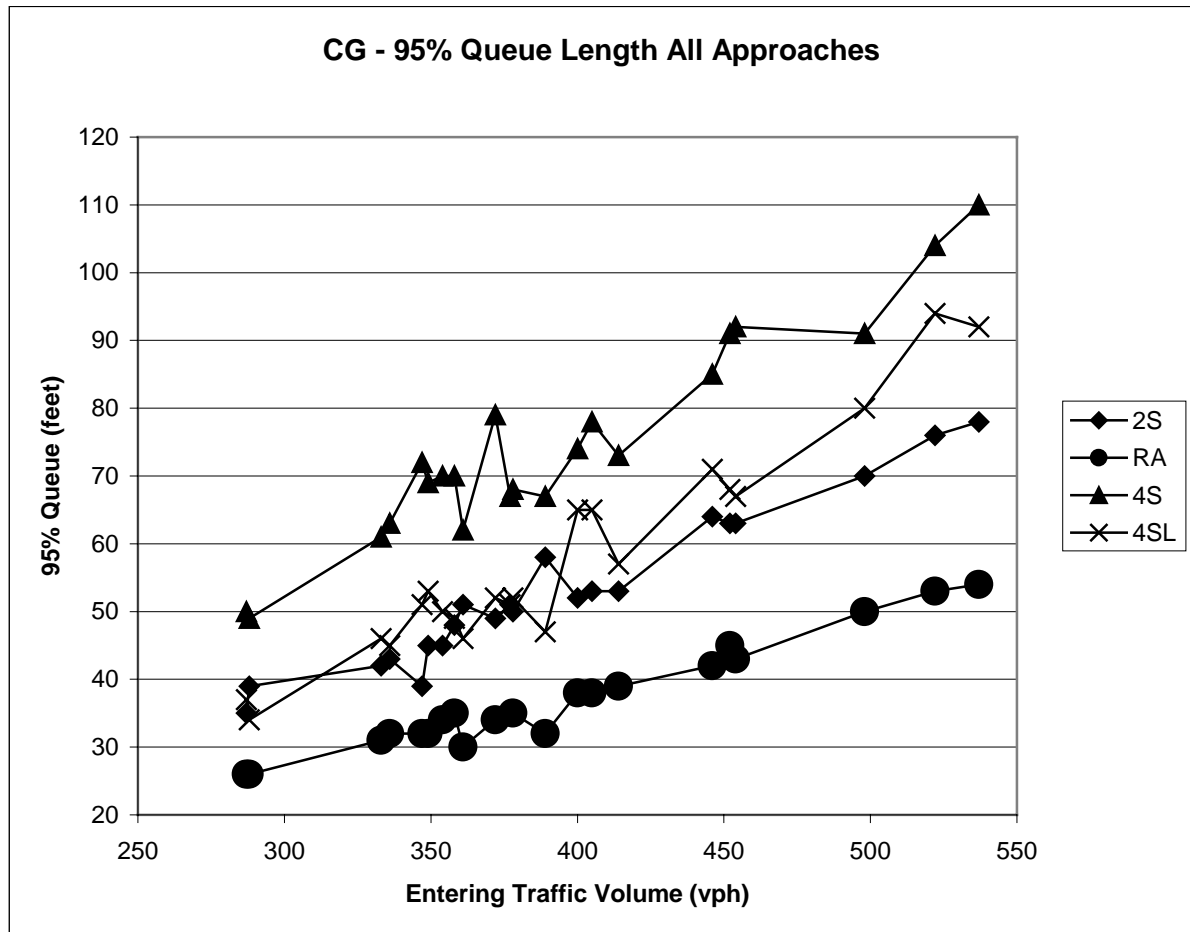
These values were tested statistically to determine if the four intersection configurations resulted in different values of 95 percentile queue.

Table 39 - 95 Percentile Queues (II)

Traffic Volume (SIDRA Hour)	two-way STOP	Roundabout	four-way STOP	four-way STOP w/Turn Lanes
287	35	26	50	37
288	39	26	49	34
333	42	31	61	46
336	43	32	63	45
347	39	32	72	51
349	45	32	69	53
354	45	34	70	50
358	48	35	70	49
361	51	30	62	46
372	49	34	79	52
377	51	34	67	51
378	50	35	68	52
389	58	32	67	47
400	52	38	74	65
405	53	38	78	65
414	53	39	73	57
446	64	42	85	71
452	63	45	91	68
454	63	43	92	67
498	70	50	91	80
522	76	53	104	94
537	78	54	110	92

The 95 percentile queue values were found to be normally distributed with unequal variances (see Table 40). Therefore, the means were evaluated using the Welch's test. This test rejected the null hypothesis of equal means. Fisher's multiple comparison concluded that the mean 95% queue value for the four-way STOP with turn lanes (4L) and the roundabout (RA) were statistically different from all others and that the two-way STOP and four-way STOP with single lane approaches were statistically similar. The mean and standard deviation values for the three intersections are shown in Table 41.

Therefore, the roundabout produces the lowest level of 95% queue over either the two-way or four-way STOP scenarios.



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 21 – 95 Percentile Queues (II)

Table 40 - Statistical Test Summary for 95 Percentile Queues (II)

Test:	Configuration:			
I. Normality	2S	4L	4S	RA
- IQR/S \approx 1.3	1.5	1.3	1.2	1.3
- Shapiro-Wilk P-value	0.24	0.05	0.30	0.05
Normal?	Yes	Yes	Yes	Yes
II. Equal Variances				
Levene's test	P = 0.0324 < α = 0.01 Fail to reject			
III.B. Normal w/ Unequal Variances				
Welch's test	P = 0.0001 < α = 0.05 Reject			
Fishers LSD groupings	4S \neq 4L = 2S \neq RA			

Table 41 - 95 Percentile Queue Mean and Standard Deviation (II)

Configuration:	Mean(μ):	Ranking*:	Standard Deviation(σ):
2S	53 ft (16 m)	B	11.8 ft (3.6 m)
4L	58 ft (18 m)	B	15.9 ft (4.9 m)
4S	75 ft (23 m)	C	15.6 ft (4.8 m)
RA	37 ft (11 m)	A	7.9 ft (2.4 m)

*Means with the same letter are not statistically significantly different.

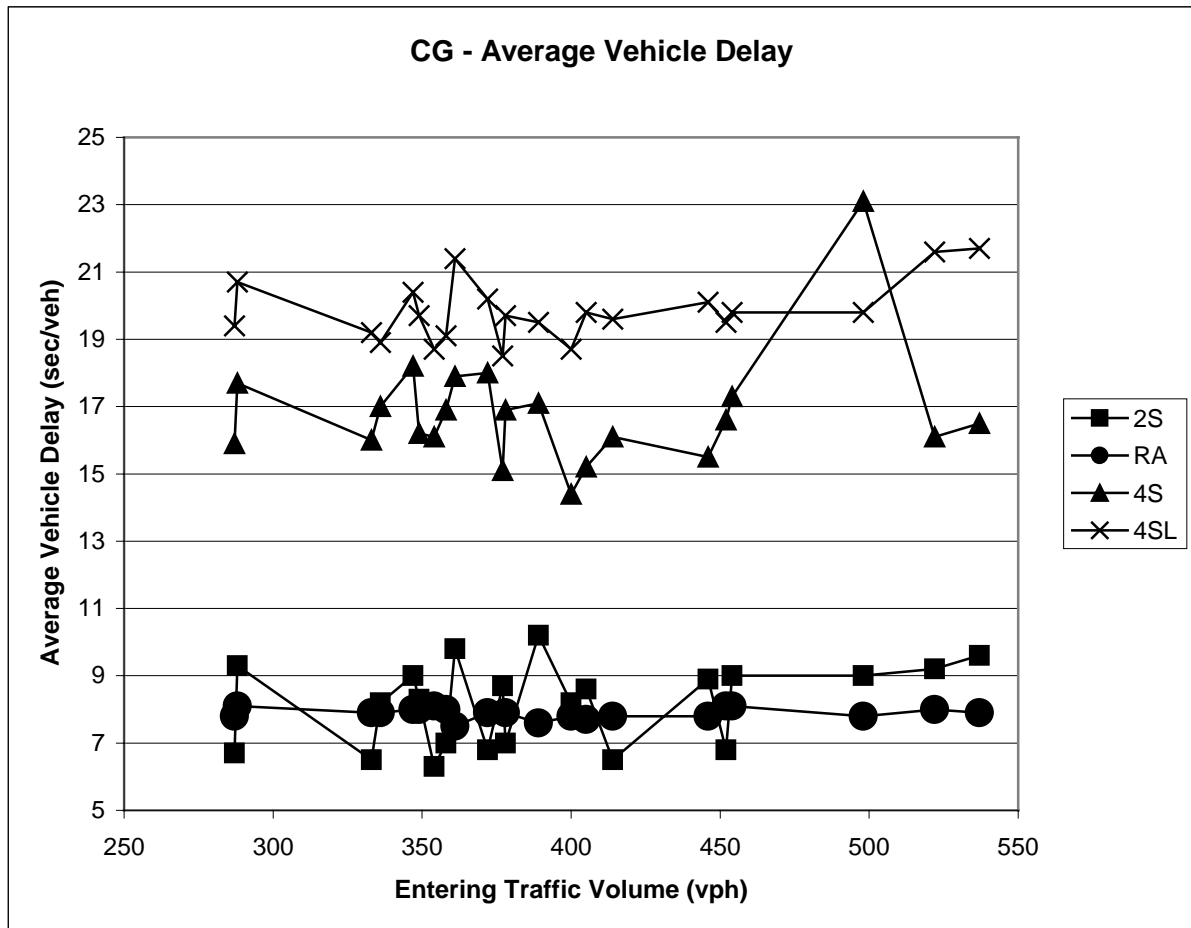
Section 9.2 – Average Delay for Candlewood Drive/ Gary Avenue (II)

The average intersection delay as described previously represents the total vehicle delay for the hour divided by the number of entering vehicles. The SIDRA output values for the average vehicle delay are shown in Table 42 and Figure 22. The values were tested statistically to determine if the four intersection scenarios resulted in different values of average delay.

Table 42 - Average Vehicle Delay (II)

Traffic Volume (SIDRA Hour)	two-way STOP	Roundabout	four-way STOP	four-way STOP w/Turn Lanes
287	6.7	7.8	15.9	19.4
288	9.3	8.1	17.7	20.7
333	6.5	7.9	16.0	19.2
336	8.2	7.9	17.0	18.9
347	9.0	8.0	18.2	20.4
349	8.3	8.0	16.2	19.7
354	6.3	8.1	16.1	18.7
358	7.0	8.0	16.9	19.1
361	9.8	7.5	17.9	21.4
372	6.8	7.9	18.0	20.2
377	8.7	7.8	15.1	18.5
378	7.0	7.9	16.9	19.7
389	10.2	7.6	17.1	19.5
400	8.2	7.8	14.4	18.7
405	8.6	7.7	15.2	19.8
414	6.5	7.8	16.1	19.6
446	8.9	7.8	15.5	20.1
452	6.8	8.1	16.6	19.5
454	9.0	8.1	17.3	19.8
498	9.0	7.8	23.1	19.8
522	9.2	8.0	16.1	21.6
537	9.6	7.9	16.5	21.7

The average delay values were found to be not normally distributed. Therefore, the distributions were evaluated using the Kruskal-Wallis test. This test rejected the null hypothesis of equal distributions. From the box plots and mean values the intersection configurations are ranked as shown in Table 43. The mean and standard deviation values for the four intersection configurations are shown in Table 44.



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 22 - Average Vehicle Delay (II)

Table 43 - Statistical Test Summary for Average Delay (II)

Test:	Configuration:			
I. Normality	2S	4L	4S	RA
- IQR/S \approx 1.3	1.8	1.1	0.8	1.3
- Shapiro-Wilk P-value	0.045	0.102	0.000	0.097
Normal?	Yes	Yes	No	Yes
II. Equal Variances				
Levene's test	P = 0.0002 < α = 0.01 Reject			
III.B. Not Normal				
Kruskal-Wallis test	P = 0.0001 < α = 0.05 Reject			
Box plot observation	RA = 2S < 4S < 4L			

Table 44 - Average Delay Mean and Standard Deviation (II)

Configuration:	Mean(μ):	Standard Deviation(σ):
2S	8.2 sec	1.2 sec
4L	19.8 sec	0.9 sec
4S	16.8 sec	1.7 sec
RA	7.9 sec	0.2 sec

Therefore, based on the average delay MOE, the roundabout and two-way STOP control can be said to be statistically similar. Both are statistically better (lower average delay) than either of the four-way STOP configurations.

Section 9.3 – Maximum Approach Delay for Candlewood Drive/ Gary Avenue (II)

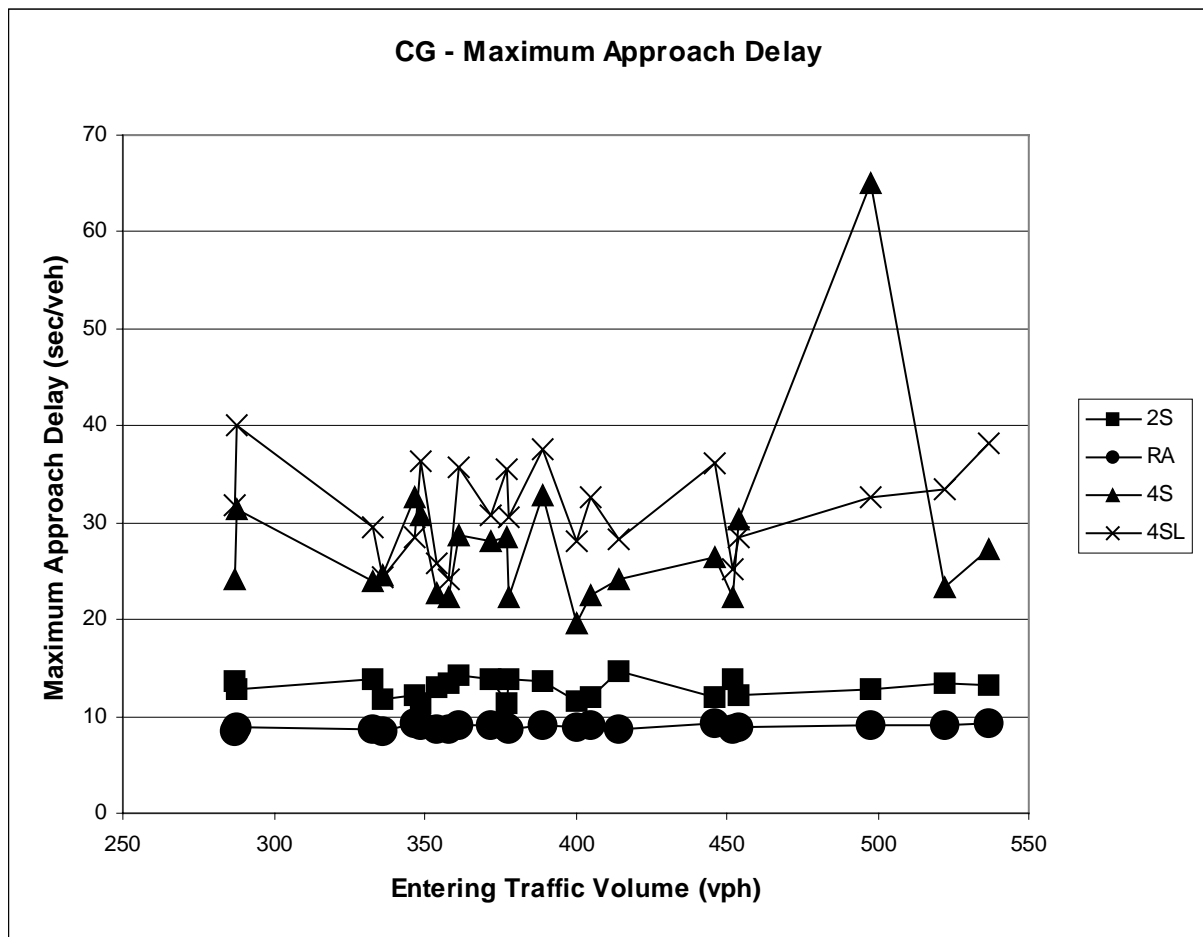
SIDRA calculates delay for the entire intersection (average delay) and then apportions this value to the intersection approaches based on the amount of entering traffic. The SIDRA output for maximum approach delay is shown in Table 45 and Figure 23. The approach that experienced the highest average delay was evaluated here to see if there were differences between the four intersection scenarios.

The maximum approach delay values were found to be not normally distributed (Table 46). Therefore, the distributions were evaluated using the Kruskal-Wallis test. This test rejected the null hypothesis of equal distributions. From the box plots and mean values it can be seen that the roundabout experiences the lowest maximum approach average delay followed by the two-way STOP and then the four-way STOPs (RA<2S<4S,4SL). The mean and standard deviation values for the three intersections are shown in Table 47.

Therefore, based on the maximum approach delay MOE, the roundabout controls the intersection better than the other three intersection control configurations.

Table 45 - Maximum Approach Average Vehicle Delay (II)

Traffic Volume (SIDRA hour)	two-way STOP	Roundabout	four-way STOP	four-way STOP w/Turn Lanes
287	13.7	8.4	24.1	31.9
288	12.8	8.8	31.4	40.1
333	13.8	8.6	24.0	29.5
336	11.8	8.5	24.6	24.3
347	12.1	9.2	32.6	28.5
349	11.4	9.0	30.8	36.4
354	13.1	8.7	22.8	25.9
358	13.5	8.6	22.2	24.2
361	14.2	9.0	28.8	35.8
372	13.8	9.0	28.0	30.8
377	11.3	8.8	28.4	35.6
378	13.9	8.6	22.2	30.5
389	13.6	9.0	32.9	37.5
400	11.6	8.8	19.7	28.0
405	11.9	9.0	22.6	32.6
414	14.6	8.6	24.2	28.3
446	12.0	9.2	26.4	36.2
452	13.9	8.7	22.3	25.2
454	12.1	8.8	30.4	28.5
498	12.7	9.0	65.0	32.6
522	13.4	9.0	23.4	33.5
537	13.2	9.2	27.2	38.1



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 23 - Maximum Approach Average Vehicle Delay (II)

Table 46 - Statistical Test Summary for Maximum Approach Delay (II)

Test:	Configuration:			
I. Normality	2S	4L	4S	RA
- IQR/S \approx 1.3	1.8	1.6	0.8	1.7
- Shapiro-Wilk P-value	0.15	0.52	0.0001	0.13
Normal?	Yes	Yes	No	Yes
II. Equal Variances				
Levene's test	P = 0.0001 < α = 0.01 Reject			
III.B. Not Normal				
Kruskal-Wallis test	P = 0.0001 < α = 0.05 Reject			
Box plot observation	RA < 2S < 4S < 4L			

Table 47 - Maximum Approach Delay Mean and Standard Deviation (II)

Configuration:	Mean(μ):	Standard Deviation(σ):
2S	12.9 sec	1.0 sec
4L	31.5 sec	4.7 sec
4S	27.9 sec	9.1 sec
RA	8.8 sec	0.2 sec

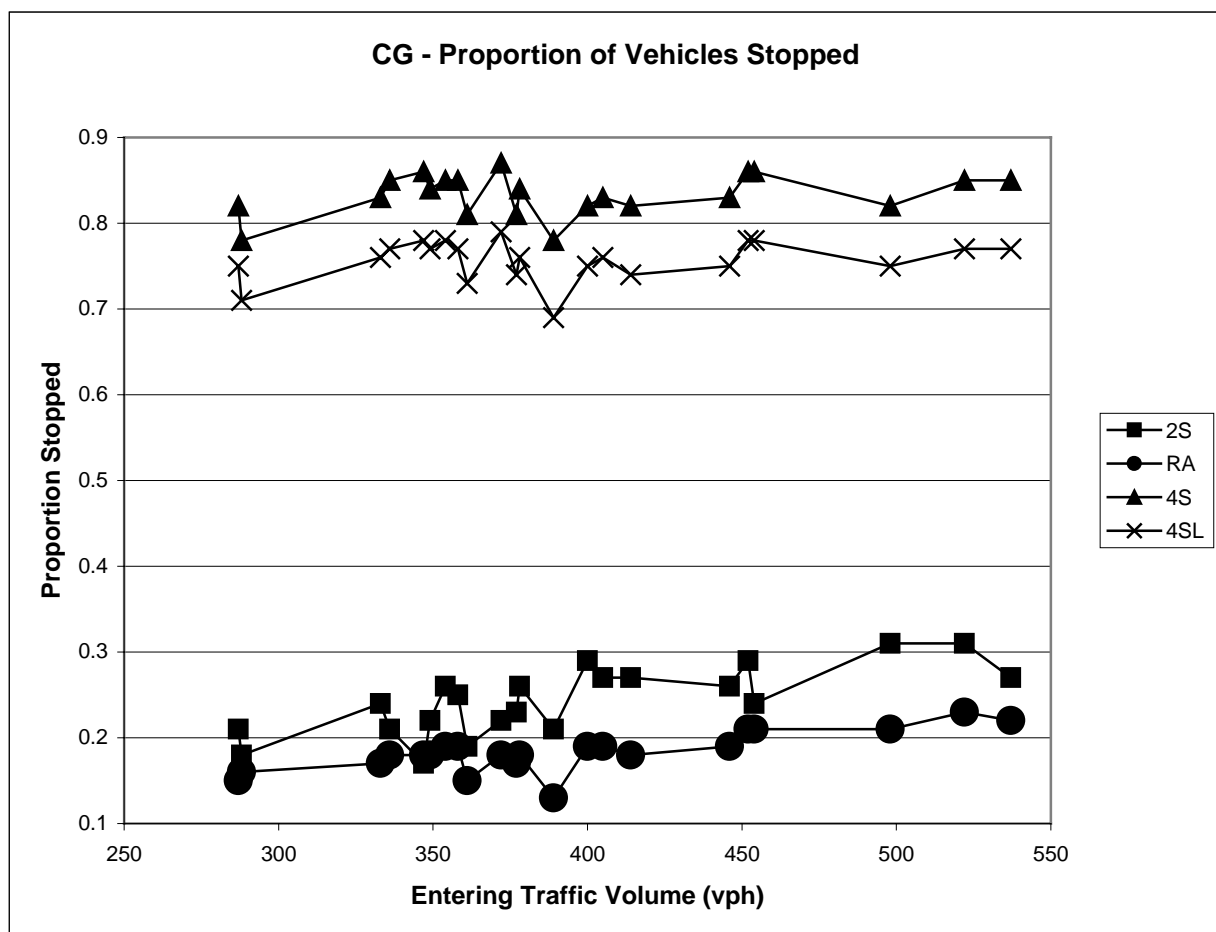
Section 9.4 – Proportion Stopped for Candlewood Drive/ Gary Avenue (II)

Statistical testing was performed to determine the proportion of vehicles from all approaches being stopped (see Table 48 and Figure 24). As with previous MOEs the testing was done to determine if there were statistical differences in the amount of stopping experienced at the four intersection scenarios (Table 49). The proportion stopped values were found to be normally distributed with equal variances. Therefore, the analysis of variance test was performed. This test rejected the null hypothesis of equal means. Tukey's and Duncan's multiple comparison tests both concluded that all four means could be considered statistically different from one another. The mean and standard deviation values for the three intersections are shown in Table 50.

Table 48 - Proportion Stopped (II)

Traffic Volume (SIDRA Hour)	two-way STOP	Roundabout	four-way STOP	four-way STOP w/Turn Lanes
287	0.21	0.15	0.82	0.75
288	0.18	0.16	0.78	0.71
333	0.24	0.17	0.83	0.76
336	0.21	0.18	0.85	0.77
347	0.17	0.18	0.86	0.78
349	0.22	0.18	0.84	0.77
354	0.26	0.19	0.85	0.78
358	0.25	0.19	0.85	0.77
361	0.19	0.15	0.81	0.73
372	0.22	0.18	0.87	0.79
377	0.23	0.17	0.81	0.74
378	0.26	0.18	0.84	0.76
389	0.21	0.13	0.78	0.69
400	0.29	0.19	0.82	0.75
405	0.27	0.19	0.83	0.76
414	0.27	0.18	0.82	0.74
446	0.26	0.19	0.83	0.75
452	0.29	0.21	0.86	0.78
454	0.24	0.21	0.86	0.78
498	0.31	0.21	0.82	0.75
522	0.31	0.23	0.85	0.77
537	0.27	0.22	0.85	0.77

Based on the statistical testing and the results shown for the proportion stopped means for the four intersection configurations, the roundabout provides the best operation with respect to this MOE.



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 24 - Proportion Stopped (II)

Table 49 – Stistical Test Summary for Proportion Stopped (II)

Test:	Configuration:			
I. Normality	2S	4L	4S	RA
- IQR/S \approx 1.3	1.5	0.8	1.3	0.9
- Shapiro-Wilk P-value	0.71	0.02	0.10	0.52
Normal?	Yes	Yes	Yes	Yes
II. Equal Variances				
Levene's test	P = 0.0101 < α = 0.01 Fail to reject			
III.A. Normal w/ Equal Variances				
ANOVA test	P = 0.0001 < α = 0.05 Reject			
Tukey's groupings	RA \neq 2S \neq 4L \neq 4S			
Duncan's groupings	RA \neq 2S \neq 4L \neq 4S			

Table 50 - Proportion Stopped Mean and Standard Deviation (II)

Configuration:	Mean(μ):	Ranking:	Standard Deviation(σ):
2S	0.24	B	0.04
4L	0.76	C	0.02
4S	0.83	D	0.02
RA	0.18	A	0.02

Section 9.5 – Maximum Proportion Stopped for Candlewood Drive/ Gary Avenue (II)

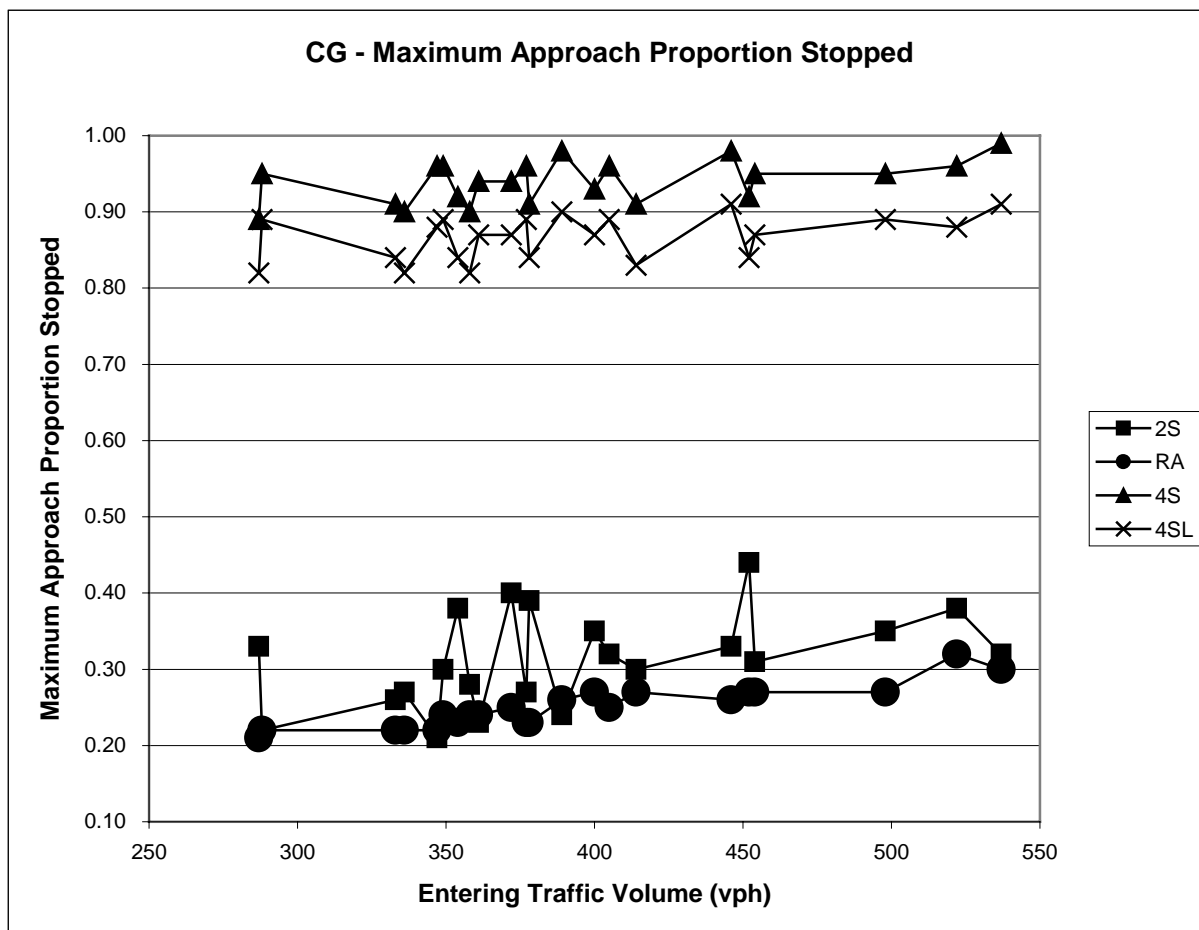
The proportion stopped values (see Table 51 and Note: Lines between data points are used only to aid in the readability of the figure.

Figure 25) were found not to be normally distributed. Therefore, the distributions were evaluated using the Kruskal-Wallis test. This test rejected the null hypothesis of equal distributions. From the box plots and mean values the intersection ranking were determined to be as shown in Table 52. The mean and standard deviation values for the three intersections are shown in Table 53.

Therefore, based on the maximum approach proportion stopped MOE, the roundabout performed better than all of the other intersection control scenarios.

Table 51 - Maximum Approach Proportion Stopped (II)

Traffic Volume (SIDRA hour)	two-way STOP	Roundabout	four-way STOP	four-way STOP w/Turn Lanes
287	0.33	0.21	0.89	0.82
288	0.22	0.22	0.95	0.89
333	0.26	0.22	0.91	0.84
336	0.27	0.22	0.90	0.82
347	0.21	0.22	0.96	0.88
349	0.30	0.24	0.96	0.89
354	0.38	0.23	0.92	0.84
358	0.28	0.24	0.90	0.82
361	0.23	0.24	0.94	0.87
372	0.40	0.25	0.94	0.87
377	0.27	0.23	0.96	0.89
378	0.39	0.23	0.91	0.84
389	0.24	0.26	0.98	0.90
400	0.35	0.27	0.93	0.87
405	0.32	0.25	0.96	0.89
414	0.30	0.27	0.91	0.83
446	0.33	0.26	0.98	0.91
452	0.44	0.27	0.92	0.84
454	0.31	0.27	0.95	0.87
498	0.35	0.27	0.95	0.89
522	0.38	0.32	0.96	0.88
537	0.32	0.30	0.99	0.91



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 25 - Maximum Approach Proportion Stopped (II)

Table 52 - Statistical Test Summary for Maximum Approach Stopped (II)

Test:	Configuration:			
I. Normality	2S	4L	4S	RA
- IQR/S \approx 1.3	1.3	1.7	1.7	1.3
- Shapiro-Wilk P-value	0.89	0.04	0.33	0.10
Normal?	Yes	Yes	Yes	Yes
II. Equal Variances				
Levene's test	P = 0.0001 < α = 0.01 Reject			
III.B. Normal w/ Unequal Variances				
Welch's test	P = 0.0001 < α = 0.05 Reject			
Fishers LSD groupings	RA \neq 2S \neq 4L \neq 4S			

Table 53 - Maximum Approach Stopped Mean and Standard Deviation (II)

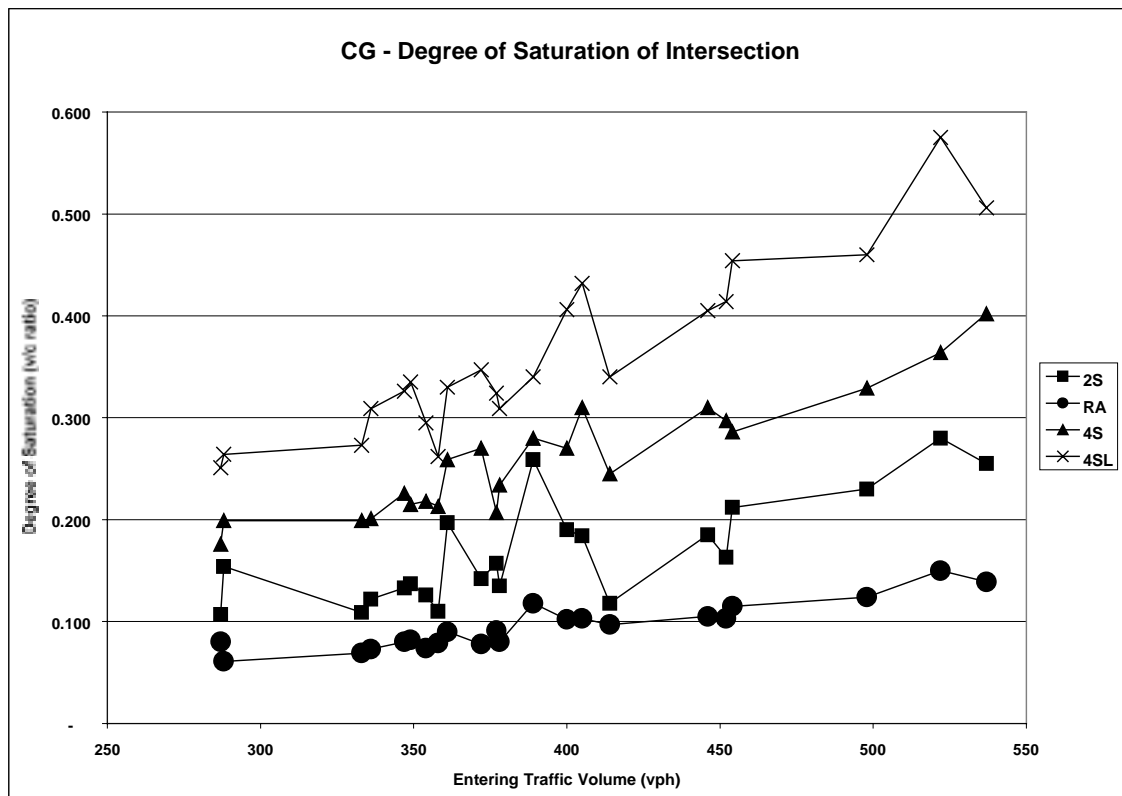
Configuration:	Mean(μ):	Ranking:	Standard Deviation(σ):
2S	0.31	B	0.06
4L	0.87	C	0.03
4S	0.94	D	0.03
RA	0.25	A	0.03

Section 9.6 – Statistical Analysis of Degree of Saturation (II)

The degree of saturation values ratio (see Table 54 and Figure 26) were found to be normally distributed (see Table 55). The means were evaluated using the Welch's test. This test rejected the null hypothesis of equal means. Fisher's multiple comparison concluded that all four means could be considered statistically different from one another. The mean and standard deviation values for the three intersections are shown in Table 56. It can be seen that with regards to the degree of saturation, the roundabout operates at a lower degree of saturation value than the other three scenarios.

Table 54 - Degree of Saturation (II)

Traffic Volume (SIDRA hour)	two-way STOP	Roundabout	four-way STOP	four-way STOP w/Turn Lanes
287	0.107	0.080	0.176	0.251
288	0.154	0.061	0.199	0.264
333	0.109	0.069	0.199	0.273
336	0.122	0.073	0.201	0.309
347	0.133	0.080	0.226	0.326
349	0.137	0.082	0.215	0.335
354	0.126	0.074	0.218	0.295
358	0.110	0.079	0.213	0.262
361	0.197	0.090	0.259	0.330
372	0.142	0.078	0.270	0.347
377	0.157	0.091	0.207	0.324
378	0.135	0.080	0.234	0.309
389	0.259	0.118	0.280	0.340
400	0.190	0.102	0.270	0.406
405	0.184	0.103	0.310	0.432
414	0.118	0.097	0.245	0.340
446	0.185	0.105	0.310	0.405
452	0.163	0.103	0.297	0.414
454	0.212	0.115	0.286	0.454
498	0.230	0.124	0.329	0.460
522	0.280	0.150	0.364	0.575
537	0.255	0.139	0.402	0.506



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 26 - Degree of Saturation (II)

Table 55 - Statistical Test Summary for Degree of Saturation (II)

Test:	Configuration:			
I. Normality	2S	4L	4S	RA
- IQR/S \approx 1.3	1.4	1.3	1.3	1.1
- Shapiro-Wilk P-value	0.05	0.09	0.20	0.15
Normal?	Yes	Yes	Yes	Yes
II. Equal Variances				
Levene's test	P = 0.0001 < α = 0.01 Reject			
III.B. Normal w/ Unequal Variances				
Welch's test	P = 0.0001 < α = 0.05 Reject			
Fishers LSD groupings	RA \neq 2S \neq 4L \neq 4S			

Table 56 - Degree of Saturation Mean and Standard Deviation (II)

Configuration:	Mean (μ):	Ranking:	Standard Deviation (σ):
2S	0.168	B	0.052
4L	0.362	D	0.085
4S	0.260	C	0.059
RA	0.095	A	0.023

Section 9.7 – Summary of Statistical Analysis II

The purpose of analyzing the MOE data was to determine if and how the four intersection control scenarios differed in operation. The same traffic count data was evaluated using the existing roundabout intersection configuration, the pre-roundabout two-way STOP configuration, and two possible four-way STOP configurations. The results of the statistical analysis of these four intersection configurations as evaluated by the six measures of effectiveness chosen are shown in Table 57.

Table 57 - Summary of MOE Statistical Results - Analysis II

Measure of Effectiveness:	Statistical Result:	Traffic Control Advantage:
95 Percentile Queue	RA < 4L = 2S < 4S	Roundabout
Average Delay	RA = 2S < 4S < 4L	Roundabout/ two-way STOP
Maximum Approach Delay	RA < S2 < 4S < 4L	Roundabout
Proportion Stopped	RA < 2S < 4L < 4S	Roundabout
Maximum Approach Stopped	RA < 2S < 4L < 4S	Roundabout
Degree of Saturation	RA < 2S < 4S < 4L	Roundabout

Under all conditions except one, the roundabout performed statistically better than the previous two-way STOP intersection control. Under all measures of effectiveness, the roundabout was found to operate statistically better than the two four-way STOP scenarios tested. All statistical testing yielded results at the 95% confidence level.